1896-1897

THE UNIVERSITY OF KANSAS,
Experimental Station,
LAWRENCE.

EXPERIMENTAL STATION.

SIXTH ANNUAL REPORT OF THE DIRECTOR,

FOR THE YEAR 1896–'97.

F. H. SNOW,
Director.

CONTAGIOUS DISEASES OF THE CHINCH-BUG.

LAWRENCE, KANSAS.
MAY, 1898.


J.SPARKS PRINTER TOPEKA

LETTER OF TRANSMITTAL.

LAWRENCE, KAN., May 1, 1898.

To his Excellency J. W. Leedy, Governor of Kansas:

In accordance with the requirements of the act making appropriation for the maintenance of the Experimental Station at the University of Kansas for the promotion of experiments for the destruction of chinch-bugs by contagion or infection, I forward to you the following report of the results of the experiments for the year 1896–'97, with an itemized statement of the money expended in the experiments.

Yours respectfully, F. H. SNOW,

Director of the Experimental Station.

CONTENTS.

INTRODUCTION.

This is intended primarily for a report of the work done at the Experimental Station during the year 1896. But since the legislature made no appropriation for the Station for the years 1897–'98 and 1898–'99, it has been deemed appropriate to include in this report a resumé of our operations with insect diseases since the beginning of our experiments in 1889. The publication of this report has been delayed, so that an account of observations and experiments carried on in the present year (1897) by the departments of botany and entomology of the University may also be included.

The Experimental Station of the University of Kansas for the consideration of chinch-bug diseases began its work in the spring of 1891. In that year, and in each succeeding year, thousands of lots of infected chinch-bugs have been distributed over the state. Infection has been introduced many times over in all the counties of the state, except in a few in the extreme west devoted chiefly to cattle grazing and where injury from chinch-bugs is of trifling extent. Besides the tens of thousands of packages of diseased bugs sent from this Station directly to individuals, innumerable others have been distributed by substations conducted by counties or private persons; and, in other innumerable instances, farmers have supplied themselves from fields of their neighbors where fungus-covered bugs could be had for the trouble of picking them up. In all that portion of the state — about three-fourths of its area — where chinch-bugs are known and dreaded, there is scarcely a square mile that has not had the *Sporotrichum* germs scattered upon it.

This thorough sprinkling of the state with spores of chinch-bug diseases has led also to the very desirable result of making the farmers familiar with the effects of the diseases and the appearance of insects infected with them. In 1889, when our experiments began, there was not a single farmer in the state, so far as we know, who could have told what was the matter with a *Sporotrichum*- or *Empusa*-covered chinch-bug, or who even knew that the little whitish particle had ever been an insect at all.

Because of the accomplishment of these two things — the thorough dissemination of the disease germs over the state and the dissemination of knowledge concerning them among the farmers of the state — it seems now to be less incumbent upon the state to put itself to the expense of maintaining, for the present at least, a central distributing station. Instead, let each field where *Sporotrichum* flourishes be a distributing point for its own immediate locality. This will be a saving of time to the farmer and money to the state.

The University, through its departments of botany and entomology, will continue laboratory and field investigations. There is yet very much to be learned toward gaining control over insect diseases. These departments of the State University will always be ready to advise or instruct farmers as to the best ways of circumventing chinch-bugs and other noxious insects, as well as noxious plants.

I desire to acknowledge gratefully my indedtedness to Prof. W. C. Stevens, of the department of botany of this University, for his invaluable assistance, during this year as in every previous year of the existence of this Station. The successful conduct of the work of the Station — in the laboratory, the field, and the office — is largely due to his conscientious services. My thanks are also due to M. A. Barber, assistant professor of botany, to F. E. Marcy, laboratory assistant, and to W. A. Snow, now of the faculty of Stanford University.

The following is the text of the act of the legislature of 1895 making appropriations for the continuation of the chinch-bug experiments:

UNIVERSITY EXPERIMENTAL STATION.

AN ACT making appropriation for maintaining the Experimental Station at the University of Kansas, at Lawrence, established to promote and conduct experiments for the destruction of chinch-bugs by contagion or infection.

Be it enacted by the Legislature of the State of Kansas:

SECTION 1. That the sum of three thousand five hundred dollars be and the same is hereby appropriated for the purpose of maintaining and conducting the Experimental Station at the University of Kansas, at Lawrence, to propagate the disease-fungi destructive to chinch-bugs, and to furnish the same to citizens of Kansas free of charge, under the direction and supervision of the chancellor of said University, Francis H. Snow, as hereinafter provided.

SEC. 2. Of the sum hereby appropriated, one thousand seven hundred and fifty dollars shall be available during the fiscal year ending June 30th, 1896; and one thousand seven hundred and fifty dollars shall be available during the fiscal year ending June 30th, 1897. The said sums to be applied to defraying the necessary expenses for assistants, experimental apparatus, expressage, telegraphing,

postage, traveling expenses of field agents, etc. The said chancellor, Francis H. Snow, is hereby authorized to issue his warrant upon the state auditor, who shall draw his warrant upon the state treasurer, upon itemized accounts, for the amounts specified by this act; and all accounts shall be verified.

SEC. 3. The said chancellor shall also make a full report to the governor on or before the 1st day of December of each year of the money expended and of the results of his experiments.

SEC. 4. This act shall take effect and be in force from and after its publication in the statute-book.

Approved March 1, 1895.

Published May 27, 1895.

INSECT DISEASES.

Nature has many ways of checking an excessive multiplication among insects; as, for instance, by periods of great cold or heat, by drought or flood, by a scarcity of food, by predaceous animals (including many carnivorous insects), or through parasitism by insects, protozoa, bacteria, and fungi. Parasitism is one of the most important of all of nature's insecticides.

"The contagious diseases of insects are all cases of parasitism, and are due most commonly to parasitic plants (bacteria and mold-like species of minute size and enormously high reproductive rate). Bacterial parasites commonly infest the insect by way of the alimentary canal, while the parasitic molds attack it from without. To this second class belong the several species of disease-producing fungi specially dealt with in this report. They may be described as minute molds which germinate and grow on the living insect, thus causing it to 'mildew,' as one may say, while it is yet alive. They start from little spores or germs of microscopic size, capable of being wafted everywhere on the lightest breeze, and sprouting on the moist surface of the chinch-bug or the cabbage-worm as grass seed sprouts on the soil; and as they sprout they send into the body of the infested creature their tiny rootlets, and speedily kill it by feeding on its blood. After the death of their host, these little plants continue to grow, penetrating and disorganizing the tissues of their victim, and if the air is moist they send tiny white threads out through the body wall, soon completely imbedding the insect as if in a delicate tuft of finest cotton. On these little threads new spores will form in unnumbered myriads, and thus the dead body becomes a center of contagion to healthy insects.

"The bacterial diseases of insects attack first the cellular lining of the alimentary canal and afterwards penetrate to the blood. Disturbance of the digestive functions is thus the primary difficulty, and the final result is a very rapid post-mortem decay of all the fluids and tissues, the body speedily becoming a filthy, semi-fluid mass."*

Protozoan diseases of insects have been studied very little, except in the case of the *pebrine* of the silkworm, which has been called the most destructive of all contagious insect diseases. Foul-brood of bees, and *flacherie*, which attacks silkworms, cabbage-worms, army-worms, and walnut worms, are examples of bacterial diseases. The muscardine of silkworms is a fungus disease, very nearly allied to the white fungus or *Sporotrichum* of the chinch-bug. This white muscardine is known to attack many other species of insects belonging to sev-

*S. A. Forbes, Nineteenth Report of State Entomologist of Illinois. I have made very free use of this admirable summary of our knowledge of insect diseases.

eral different orders. The gray fungus of the chinch-bug, called in our reports *Empusa aphidis*, is nearly related to the common house-fly fungus.

Dr. Henry Shimer, of Illinois, was the first to observe the outbreak of a contagious disease among chinch-bugs. In the Proceedings of the Philadelphia Academy of Sciences for 1867 he gives an account of the destruction of chinch-bugs in Illinois in 1865 by what was undoubtedly *Sporotrichum* or *Empusa*. He described the disease as an "epidemic doubtless produced in a measure by deficient light, heat, and electricity, combined with excessive humidity of the atmosphere, whereby an imperfect physical organization was developed." While Doctor Shimer did not understand the nature of the disease, he was, nevertheless, in advance of his entomological contemporaries—Walsh, of Illinois, and Riley, of Missouri—who ridiculed the idea of a contagious disease among chinch-bugs. Ten years later, Dr. Cyrus Thomas was the first to suggest the true character of the disease:

"The first definite suggestion among us of the possibility of the economic use of fungus insect disease was made by the well-known coleopterist, Dr. J. L. LeConte, in 1873, when, in a public address, he recommended 'careful study of epidemic diseases of insects, especially those of a fungoid nature, and experiments on the most effective means of introducing and communicating such diseases at pleasure.'"

If we omit an account of the experiments of Dr. H. A. Hagen, of Harvard University, in 1879, toward the use of yeast as an insecticide, based on a misconception of the nature of the yeast plant, the first experimental work with insect diseases was taken up in 1883 by Doctor Forbes. In that year he began the study of the cabbage-worm disease, which he identified with *flacherie*. He made cultures of bacteria from the alimentary canal and body fluids of sick larvæ, and conveyed the disease to distant points by sending dead diseased caterpillars as an infection material, thus being undoubtedly the first to successfully use those methods of contagion which we have employed on so large a scale among chinch-bugs in Kansas.

CONTAGIOUS DISEASES OF THE CHINCH-BUG.

To Doctor Forbes more than to any one else are we indebted for our knowledge of the two fungus diseases of the chinch-bug. He first observed the gray fungus (*Empusa aphidis*) in 1882, and in 1887 he found the white fungus (*Sporotrichum globuliferum*) infesting chinch-bugs in Illinois. To Doctor Forbes belongs the credit of being the first to discriminate between the two diseases (*Empusa* and *Sporotrichum*).

In 1888 wide-spread destruction to chinch-bugs by spontaneous fungus disease was reported by Doctor Forbes in Illinois, by Professor Lugger in Minnesota, by Professor Gillette in Iowa, and by myself in Kansas. Professor Lugger was the first to endeavor to spread the disease by sending into different parts of the state packages of dead bugs.

From 1888 to the present time, those outside of Kansas who have been especially active in studying the disease of the chinch-bug have been Professors Forbes in Illinois, Lugger in Minnesota, Webster in Ohio, Osborn in Iowa, and Bruner in Nebraska. Professor Webster made the first careful experiments to determine the effect on the fungus of weather conditions. Professor Forbes has found that the supposed bacterial disease of the chinch-bug, *Micrococcus insectorum*, is not really a disease, but that the presence of this bacterium in the chinch-bug, and of similar ones in other Hemiptera or true bugs, is a condition normal to the gastric pouches of these insects.

In reviewing the recent work of these other investigators, I can do no better than make extracts from their published reports.

Doctor Forbes in his last report * has added to our knowledge of the life-history of the chinch-bug. The experiments were made by an assistant, Mr. W. G. Johnson.

"The rapid increase of the chinch-bug under favorable circumstances is of course dependent primarily on its normal breeding rate, but just what that rate is has not hitherto been precisely ascertained. It has been commonly asserted, indeed, since 1867 that the number of eggs deposited by a single female is about 500, but this was a mere estimate based on general field observations made in

*Nineteenth Report Entomologist of Illinois, 1896, pp. 177, 178.

1865 by Dr. Henry Shimer, of Mt. Carroll, Ill. On this point Shimer says: 'The parent chinch-bug is occupied about twenty days in laying her eggs, during which time she probably lays about 500 eggs and then dies.'

"From Mr. Johnson's report of the experiments above mentioned, we learn that a single female chinch-bug kept under the most favorable conditions may deposit as many as 237 eggs, but probably few, if any, more; that the egg-laying period lasts about forty days, or double the number above given; that pairing takes place, in the summer generation, from four to five days after the female sheds her pupal skin; that the first eggs are laid in two or three days after pairing, six to eight days after the pupal skin is cast; that the average length of life of the adult female of the summer generation is about fifty days, and that of the male about seventy-eight days; that the female pairs very frequently, perhaps every day, during the egg-laying season; and that the eggs may hatch in from eighteen to twenty-one days after deposition, or an average of about twenty days.

"The disappearance of the chinch-bug after a season of extraordinary abundance is most commonly attributed to the immediate effect of wet weather, and no general idea concerning its economy is more firmly fixed than the supposition that even ordinary summer rains will destroy it outright. Nevertheless, no precise investigation of its ability to endure submergence has ever been reported, and this supposition is really based on superficial observation. The results of our experiments on this point may be summed up as follows:

"Chinch-bugs just emerged from the egg will survive a complete immersion of one to three hours; young of the first molt, three to five hours; of the second molt, six to nine hours; and of the third molt (pupæ), eight to thirteen hours. Adults of the summer generation will live under water from twelve to twenty-two hours, and those of the fall generation have revived after thirty to fifty-four hours' complete submergence.

"Chinch-bugs just emerged may live floating on the surface of water seven hours, while those of the second molt may revive after twenty-three hours. Bugs of the second molt have lived two and a half days under such conditions; those of the third molt (pupæ), three and three-fourths days; and adults, about fifteen days. Chinch-bugs have even molted while in this situation, the wings and crust of the adult hardening, as if the insect were free."

On the spontaneous occurrence of the *Sporotrichum* disease the same author says:*

"Notwithstanding the prevalent droughts of 1891, 1892, and 1893, and the consequent absence of any considerable outbreak of contagious disease among chinch-bugs, as well as the failure of all our attempts at the artificial introduction of white muscardine in Illinois, a sufficient number of fungus-covered specimens were found from time to time in widely separated places to show the presence of that disease in here and there a locality. *Sporotrichum globuliferum* seems, in fact, very commonly, if sparingly, present among insects in this latitude in a condition to give local origin to this fungus attack whenever favoring circumstances supervene."

Doctor Forbes summarizes the results of investigation of *Sporotrichum*, as follows:†

"1. While muscardine of the chinch-bug is a contagious disease due to parasitism by the fungus species *Sporotrichum globuliferum*, it affects a large num-

*Ibid., p. 25. †Ibid., p. 29.

ber of other insects as well, and probably never dies out entirely over any large area of the state, but is always sufficiently prevalent and common under all conditions to furnish a suitable beginning for a spontaneous spread wherever an insect species, like the chinch-bug, becomes for a time superabundant under conditions favorable to the growth and reproduction of the fungus characteristic of this disease.

"2. The conditions necessary to its appearance among chinch-bugs on the epidemic scale are an abundance of the bugs themselves and a considerable amount of wet weather, with not too low an average temperature.

"3. Its hidden presence among bugs which, as observed in the field, seem to be wholly free from it may often be demonstrated by shutting up such bugs for two or three days in a moist atmosphere; but, on the other hand, as this procedure often fails to develop it, it is not always and everywhere present.

"4. Its characteristic fungus may be easily cultivated on certain mixtures of animal and vegetable substances, or on either of these substances alone—plain beef broth or simple agar-agar, for example. The cheapest and most satisfactory mixture thus far used is corn-meal saturated with beef broth.

"5. It can only be grown on these media in the absence of the germs of fermentation and decay. If these are not excluded, they take possession of the surface, and the muscardine fungus will not grow in competition with them; methods of sterile culture are therefore indispensable. The most convenient apparatus of sterile culture used by us is a circular copper pan, nine inches across and one inch deep, with straight sides, and a cover which shuts over the pan like the lid of a pill-box. A less convenient but slightly safer apparatus is a Mason fruit-jar, with the metal cap altered by the insertion of a tube, which may be plugged with cotton, as a protection against bacteria and other fungus germs.

"6. Propagation of this fungus to living insects is easy if the atmosphere is kept moist. We have found as yet little, if any, reason to believe that the cultivated *Sporotrichum* is any less active as an agent of infection than that grown on the insect body. Its spores will germinate on the surface of infected insects, sending their thread-like outgrowths through the cuticle; but soft-bodied forms, like caterpillars, are, as a rule, more easily infected than those with a hard crust.

"7. The distribution of the *Sporotrichum* in the field will have no immediate effect if the weather is dry, but spores may live in a dry state for many months, and may thus give origin to an outbreak of muscardine, if the weather changes, long after they have been distributed.

"8. The readiest and most convenient method of rapid propagation and general distribution of muscardine is to grow the fungus on corn-meal batter mixed with beef broth by the sterilization methods of the bacteriological laboratory, and to distribute this cultivated fungus to farmers, with instructions for its use. For its dissemination in their fields, chinch-bugs are to infected by exposure to the fungus in tight wooden boxes, with a layer of earth in the bottom of each box. The imprisoned bugs must be supplied with food, which should be renewed as necessary, and the contents of the boxes must be kept continuously moist. As the bugs show evidence of disease, a part of them are to be scattered in the fields at intervals, their places being taken by fresh bugs put in the box. This operation is to be continued until the desired result appears. A more convenient method, and one less liable to miscarriage through failure of the farmer to carry on successfully operations for the propagation of the fungus, is the cultivation of spores in sufficient quantity to permit their direct application in the field. This would require, however, a very large central plant for cultivation and dis-

tribution, and is not to be recommended until the economic value of the whole method has been more satisfactorily tested. It seems barely possible that culture methods may be so simplified by further experiment as to bring them within the resources of the intelligent and careful farmer.

"9. The precise economic value of this method is not as yet, by any means, fully known. It seems to be, in Illinois, at best a means of hastening the appearance of the muscardine and of accelerating its spread among chinch-bugs under favorable weather conditions; but how much it may actually hasten either the appearance or the spread the remains yet to be ascertained.

"We may say, in brief, that the agricultural effect of a chinch-bug attack is to hasten and intensify the evil consequences of drought; and that the contagious disease of that insect here treated has merely the effect to hasten and intensify the beneficial consequences of wet weather."

Doctor Forbes gives the following suggestion * with regard to surrounding the infected material after it has been placed in the field, with the most favorable conditions for the spread of the disease:

"It is most likely to 'catch' in low spots, where the soil is kept somewhat moist by dense vegetation, a mat of fallen herbage, or the like. Shocks of corn, especially when the crop is cut early, furnish excellent places for the development of this disease. Indeed, the presence in any field of spots especially favorable to the growth of the *Sporotrichum* infection seemed, according to our observations, to have much more to do with the appearance and spread of the white muscardine among chinch-bugs than even the most persistent distribution of dead or infected specimens in the absence of such natural culture beds—a fact which contains the suggestion of a new method for the propagation and dissemination of this disease. *It will be well worth while, consequently, to try the effect of excessive moisture and an inviting shelter on here and there a spot in an infested field, such as might be afforded by an overgrowth of small grain produced by heavy fertilization, or by tramping down a few hills of corn, or by the early cutting and shocking of some small part of the crop. If no spontaneous development of muscardine were to follow, such spots would at any rate be excellent places to start a field infection.*"

The coal-tar-barrier method of killing the bugs when they are passing in masses from the small grain into the corn was tried by Doctor Forbes with success.† He says: "It compares most favorably with the use of contagious diseases, resulting in the wholesale destruction of untold myriads of bugs, and being independent of the weather and other uncontrollable elements of the situation."

In a recent article, "Three Years' Study of an Outbreak of the Chinch-bug in Ohio," ‡ Prof. F. M. Webster, state entomolo-

---

* Ibid., p. 92.

† Ibid., p. 5.

‡ Bulletin 77, Ohio Agricultural Experiment Station, 1897.

gist of Ohio, gives the following account of the artificial spreading of the white muscardine in that state last year:

"I have always held to the opinion that the parasitic fungus, *Sporotrichum globuliferum*, could only be used, in a manner to offer relief to the farmer, during wet seasons, and where there was a superabundance of the host insect, and, though I have been severely criticized, am of this opinion still. For years I have been waiting such a combination of conditions, as they do not often occur, owing to the fact that wet weather during the hatching season is fatal to a large per cent. of the young, but not until the present year have my hopes and desires in this direction been gratified. To learn that a measure will fail under adverse conditions is but half satisfactory, and before one can feel at all satisfied the same measures must be tested under favorable conditions.

This year I can say that, with all conditions favorable, Sporotrichum globuliferum has done all that Professor Snow or any other entomologist has claimed for it, but under conditions as adverse as these have been favorable, the results will prove quite the reverse. While I do not find any reason for the immunity from attack, this year, over the area where this fungus was distributed last year, believing that this can be accounted for by peculiar meteorological conditions, **it saved farmers thousands of dollars where it was used this season.** Where applied early in June, though it did not save the wheat crop, it did in many cases so reduce the number of bugs before they had advanced far into the corn-fields that they were rendered powerless. In wheat-fields, where an early application was made, the furrows and other depressions in the surface were soon white with diseased bugs, and in the mellow ground of the corn-fields a slight displacing of the upper surface with the foot would reveal myriads of their dead bodies intermixed with the soil. One farmer told me that upward of 1000 neighboring farmers had visited his fields to secure dead bugs to place in such of their own fields as were infested, and I have myself seen good results from this method of introduction, taking pains to compare the conditions in such fields with those existing where *Sporotrichum* had not been introduced, and where careful search failed to reveal its presence.

"While the practical value of this fungus has, in past years, probably been overestimated, it is to be regretted that there is at present a tendency to rush to the opposite extreme. **Statements to the effect that it is of no value to the farmer, or that artificial introduction is useless, as when the conditions are favorable it will appear in a natural manner and do its work, are, to say the least, ill advised, and true only under certain conditions.** It is worthless to the farmer during a period of drought, or when the bugs are scattered, but it is practical and effective under conditions the reverse of these. It will sometimes appear in the fields in a perfectly natural manner, but this is uncertain, and *we have here only one of many instances where science can and does facilitate and accelerate the usually slow mechanism of nature.*"

In 1896 Prof. Otto Lugger, state entomologist of Minnesota, supplied over 1200 farmers with spores of *Sporotrichum*. I take from his report* the following interesting statements: "Whether it is a coincidence or not, one thing became very apparent: wherever large numbers of the disease spores had

*Second Annual Report of the Entomologist of the State Experiment Station of the University of Minnesota, 1896.

been scattered during 1895, few chinch-bugs survived autumn, winter, and spring; and in some localities, where the bugs had been exceedingly numerous before, but few, if any, could be found early in 1896." He says further, that "the climatic conditions of the season of 1896 were such that the chinch-bug disease worked to the satisfaction of all who tried it conscientiously, and if it had been more generally employed in all infested counties a chinch-bug plague could have been prevented for a great number of years, as most of the few found in the fields could have been killed. Where those to whom infection was sent applied it thoroughly and according to directions, success followed." Professor Lugger is not entirely satisfied with the *Sporotrichum*, and expresses a doubt as to whether the disease attacks healthy bugs or only those feeble ones that would die whether or not the disease is present.

WHAT HAS BEEN DONE IN KANSAS.

A HISTORY OF THE PRACTICAL APPLICATION OF THE CHINCH-BUG DISEASE IN KANSAS.

1888.—In 1888 I first became acquainted with the effect of fungus diseases upon chinch-bugs. April and May of that year was a period of dry weather. The chinch-bugs were numerous and threatened the destruction of the crops. Farmers began to plow under their oats and wheat. But suddenly the chinch-bug armies began to disappear, the crops revived, and the farmers were able to reap bountifully where utter loss had been impending. On investigating the causes of the disappearance of the bugs, I discovered that millions of them had died from the ravages of a fungus disease, and, in an article published in the Sixth Biennial Report of the Kansas State Board of Agriculture, I expressed the opinion that, "in the warfare of man against his insect foes, a most valuable ally will be found in the bacterial and fungoid diseases which may be artificially introduced when nature fails to come to our aid."

1889.—In 1889 our laboratory experiments were begun with bugs dead from the "gray fungus," *Empusa aphidis*, received from Dr. J. T. Curtis, of Dwight, Morris county, Kansas. I soon established the fact that this disease could be communicated to live bugs in the laboratory, and, as soon as this result had found its way into the newspapers, I was besieged with applications for infected material by farmers in many of the western states.

I believe I was the first to successfully inoculate with fungus healthy bugs in the laboratory to be used for spreading the disease at distant points. Highly colored newspaper accounts led people to believe that I was the discoverer of the disease, or even the inventor, for it was believed by many that I had compounded some drugs that could be used, poison-like, to kill the bugs, or to bring upon them an insanity that drove them to their own destruction.

Even this notoriety had its use, and I was able to experiment on a large scale by reason of it, and in widely separated parts of the country.

1890.—The year 1890 was not a chinch-bug year in Kansas. Notwithstanding the fact that it was very dry and some parts of of the state suffered from severe drought, up to the middle of July I received but three applications for disease germs. During the whole year but thirty-eight boxes of infected bugs were sent out. Experiments in the laboratory were continued, and our methods of inoculating bugs were improved.

1891.—In the winter of 1890–'91 the legislature of the state of Kansas made provision for the establishing and maintaining of the Experimental Station at the University of Kansas for the propagation of contagious diseases of the chinch-bug and the free distribution of the infection to farmers. The sum of $3,500 was appropriated, to be expended under my supervision during the two years 1891, 1892. The funds became available in March, 1891, and immediately arrangements were made for the infection of chinch-bugs on a large scale. A laboratory was equipped for the study of insect diseases. Farmers who applied for the disease germs were required to send to us a quantity of live bugs, and in return were furnished from eight to a dozen spore-covered bugs. More than 2000 persons were thus supplied, resident in seventy-eight counties in Kansas and in twelve other states. Of this number of experimenters, reports were received from 1399. Of these reports, 1071 (or 76.55 per cent.) indicated success; 181 (or 12.94 per cent.) indicated failure; and 147 (or 10.51 per cent.) were doubtful; 482 of the successful experimenters gave their own estimates of the number of bushels of grain saved by the experiment. The sum of these estimates amounted in cash value to $87,244.10, or an average of $181 for each farmer. The year was a very wet one, but the chinch-bugs were generally prevalent in great numbers.

1892.—In this year about 3000 lots of diseased chinch-bugs were sent out from the Station into seventy-seven counties of the state, and ten states and territories other than Kansas. Of those who reported the outcome of their experiments, 67.9 per cent. reported it as successful, 24.3 per cent. as unsuccessful, and 7.8 per cent. as doubtful; 383 of the successful experimenters estimated their savings by use of the infection at $39,481.15.

1893.—The legislature of the state of Kansas for the winter of 1892–'93 appropriated $4500, of which sum $1000 was to be

available during the fiscal year ending June 30, 1893; $1750 was to be available during the year ending June 30, 1894; and $1750 was to be available during the year ending June 30, 1895.

In this year more than 8000 packages of infected material were sent out from this Station. Farmers in eighty-four Kansas counties were supplied. A small proportion of the packages was sent to farmers in other states. Reports were received from 3,570 of the Kansas experimenters and from 233 of those living outside the state; 52 per cent. of the experimenters reported success; 29.5 per cent. reported failure; and 18.5 per cent. reported doubtful results. The aggregate estimate of 326 correspondents of the value of crops saved by the application of the *Sporotrichum* was $55,000.

Substations for the distribution of disease spores were maintained in twenty counties of the state, either by private persons or by county commissioners. Several thousand farmers were supplied by these. This system did not work well in all cases, owing to the carelessness or ignorance of the conductors of the substations. It was found necessary to keep an assistant in the field during the greater part of the season, to supervise these stations. Many parts of the state suffered this year from drought.

1894.—No fewer than 8,000 packages of infection were sent out to individual farmers in Kansas, Missouri and Oklahoma during this season. In addition to the distribution of infected material from this Station, fifty auxiliary stations were established in as many different counties in Kansas and Missouri; thirty-eight of these stations being located in Kansas, and twelve in Missouri. It is estimated that on an average each of the fifty substations supplied 300 farmers, giving a total of more than 15,000 farmers supplied with infection from this source. It would thus appear that upwards of 20,000 farmers in Kansas, Missouri and Oklahoma were furnished with *Sporotrichum* germs during the year 1894. And in addition many more supplied themselves from neighboring farms where the disease was present. Reports were received from over 3,000 experimenters, and on the face of these reports fifty-five per cent. of the experiments were successful. No substation was allowed to be established unless the individual who was to take charge of the station should first have visited the laboratory of the central

Station for the purpose of obtaining instruction as to the identification of the true parasitic fungus as compared with other fungi readily mistaken for the genuine parasite by an uninstructed observer, and also as to the proper method of propagating the infection at the substation.

During this year the northeastern counties of Kansas were the chief sufferers from the chinch-bug, while counties in the southern third of the state, where in preceding years the bugs had done great damage, suffered comparatively little. This condition was indicated by the fact that in 1894 there was a decrease of 85 per cent. in the amount of infection sent to the southern counties and an increase of 140 per cent. in the amount sent to the northern counties. At the same time the meteorological conditions in these two areas were not unlike. While *Sporotrichum* had carried off many of the bugs in the southern counties during the preceding years, yet there is no actual proof that the comparative scarcity of them was caused by that agency. By the farmers themselves it was ascribed to that cause.

1895.—The rainfall for the first five months of this year in eastern Kansas was very deficient. At the University it was smaller than in any season during the preceding twenty-eight years. Attempts to introduce disease among the bugs during this dry period were, in very many cases, unsuccessful. The early wheat harvest, consequent upon the spring drought, compelled the bugs to seek the corn while it was very young, and the injury inflicted upon it was very severe. Later in the season, with the rains, came disease, and immense numbers of the bugs perished. In such a season as this one the farmer should use every available weapon in his warfare against these enemies. One of the best of these weapons is the construction of barriers at the time when the bugs in vast hordes are making their way from the wheat-fields to the corn-fields. During this season experiments were carried on at the Station to determine the most efficient barrier. A detailed description of experiments with these barriers is given below, in our report for 1896. This barrier is simple, inexpensive, and, if made at the right time, will bring great destruction to the bugs before they have a chance to attack the corn.

Experiments begun in 1894 to test the efficiency of introduc-

ing the fungus by spraying with water containing spores were continued during this season. The method did not prove successful.

In 1895, 3006 packages of infection were sent out to individuals in Kansas; 1040 were sent to individual applicants in seventeen other states and territories, over half of these going to Missouri and Oklahoma. The number of packages sent out in bulk for distribution was 2223 in Kansas and 992 in other states, making a total number of packages sent out of 7271.

EXPERIMENTS AND OBSERVATIONS IN 1896.

Sporotrichum.—While no such general epidemic of *Sporotrichum* was noted in this year as occurred in 1895, yet the disease seemed present in those parts of the state visited, wherever favorable conditions existed, and in fields whether artificially infected or not. Fewer applications for infection material were received in this year than in 1895 which may be accounted for by the prevalence of *Sporotrichum* in the fields and because by this time farmers have pretty generally been taught the appearance and methods of use of the diseased bugs. Wherever these are to be obtained in neighboring fields there is no necessity of applying to the Station.

From studies made in the hibernating period, *Sporotrichum* was proved to be present among the bugs in three counties of the state in January, February, March, and April. It became most abundant in June, over the state in general, when it diminished in quantity, and in August comparatively little could be found in the fields, even where the bugs were numerous and the conditions not unfavorable. Bugs kept in infection boxes in August and others taken from their winter quarters in November showed very little of the disease. Though the winter was a very humid one and *Sporotrichum* was present, the bugs did not die from the disease in their winter quarters. Indeed, we have never known chinch-bugs to be killed by *Sporotrichum* in their winter quarters, nor to be thus killed in the field at any time when the daily temperature does not rise to at least 70° Fahrenheit.

Empusa aphidis.—Empusa was found on the bugs in their winter quarters, and later to some extent, but was of far less importance than *Sporotrichum*.

No Bacterial Disease Found as Yet.—We have found no real evidence of the existence of a true bacterial disease. Dead bugs are often found in the field, and commonly in the infection boxes, that show no signs of the presence of a fungus, but have their bodies swollen up to twice their normal size. At first we thought that these were bugs killed by a bacterial dis-

ease, but a microscopic examination of their body fluids reveals no form of bacterium that may be distinguished from the ordinary one which accompanies decay.

Effect of Hard Rains on Chinch-bugs.—I am now more than ever convinced of the ineffectiveness of rain-storms as an insecticide in the case of chinch-bugs. After one of the hardest downpours of rain that I ever witnessed, I observed bugs of all ages to be agile and unharmed, and, as near as I could tell, in as great numbers as before the rain. Patient search with a hand lens revealed no bugs beaten into the ground. Water standing in the furrows contained no drowned bugs. Young bugs not two days removed from their eggs were busily at work unseparated from the numerous brothers and sisters of their family.

The Burning of Bugs.—The burning over of waste and uncultivated lands in early spring has been recommended as a feasible measure against the chinch-bug. In most Kansas localities there is much too great an area which furnishes wintering places for the bugs to be burned over; and, as shown in an experiment by Mr. Barber, many bugs may escape where the fire does not burn close to the ground.

Effect of Freezing on Chinch-bugs and Sporotrichum.—As shown by experiment, the freezing of chinch-bugs in a cake of ice for two or three days will not be sufficient to kill them. *Sporotrichum* frozen solidly for forty-three days retained its vitality.

Hibernation of Chinch-bugs.—The favorite hibernating places of the bugs were found to be dense tufts of prairie-grass, where they lay at the very bases of the tufts, beneath the old grass matted close to the ground. They seemed rarely to winter in corn-stalks, even when these were shocked. They were found in numbers in a large variety of situations.

Barriers and Post-hole Traps.—The barrier method for excluding bugs from corn-fields by means of ridge, coal-tar line, and post-hole traps, was experimented with extensively this year, and some conditions essential to its effectiveness were demonstrated which were not revealed by our 1895 experiments because of some very different meteorological conditions. In 1895 the early part of the season was unusually dry, and even before the small grain was cut the bugs were in need of new pastures, and were migrating *en masse* to the corn-fields when

the corn was yet young. Under such circumstances the barrier was found to be entirely successful.

The spring of 1896 opened with an abundance of moisture in the soil and atmosphere. The corn was already well advanced before the small grain had ripened, and after the small grain was cut the short grass, which had grown up amongst the wheat luxuriantly in the moist soil, furnished an agreeable pasture for the bugs, so that they entered the corn-fields tardily, their migration being extended over a period of two months. Under such conditions, no material damage was done to the corn even where no protection was attempted, and where the barrier was used the expense of keeping it in good condition during the long migration period was not warranted by the results obtained. The status of the barrier, then, is, that when the corn is most in danger because of dry weather and the onslaught of large numbers of bugs at once, the barrier is a feasible remedy; but if the weather is sufficiently wet to result in good pasturage for the bugs in the small-grain fields even after harvest, the barrier would probably not pay for itself.

We believe that the barrier as constructed by Mr. F. E. Marcy, an assistant of the Station, with his ridge-former, is the best that has yet been devised. During the past summer Mr. Marcy experimented with different sorts of barriers, but the ridge, as described in our report for 1895, has given the best results. Coal-tar was found to be far superior to kerosene oil and salt, under the conditions that prevailed during the past season, and the former is therefore recommended as the most reliable for all seasons. On the pages following will be found a detailed account of experiments carried on in one field, which gave results essentially the same as did the other fields experimented with.

OBSERVATIONS ON THE HIBERNATION OF CHINCH-BUGS AND SPOROTRICHUM.

By M. A. Barber.

Observations were made at different times throughout a period extending from December, 1895, to April, 1896, to determine, first, the location and number of hibernating chinch-bugs; and, second, whether *Sporotrichum* in a living condition was present among them during the winter. These observations were made in Coffey, Douglas and Jefferson counties.

For the most part, bugs were found in dense tufts of prairie-grass, at the very bases of the tufts, and in the shelter formed where the old grass lay matted closed to the ground. As a rule, the bugs were mostly at the surface of the ground, although sometimes they were found in the axils of the grass blades. Generally, where the surface of the ground was irregular, they were found in the upper, drier parts of the furrows. Bugs were found in other places also; among leaves and other rubbish under hedges, under stones, among leaves in the woods, and in similar places. They were found in comparatively few instances in corn-stalks, whether standing in the field or in the shock, and they were very rarely found hibernating in green wheat.

The hibernating places were, as a rule, near cultivated fields, but not necessarily near a place where the bugs were numerous during the preceding summer. In one locality in Coffey county, bugs hibernated in large numbers during the winter of 1895–'96, and were plentiful in the same shelters in November, 1896; but an examination of the vicinity in June, 1896, showed no bugs in the corn, oats or crab-grass growing near by.

There seems to be little hope in most Kansas localities of materially reducing the numbers of chinch-bugs by burning grass and other rubbish in early spring, even though there should be concerted action on the part of many farmers. There is so much uncultivated ground, and so many localities furnish shelter for the bugs, that it would be difficult to burn over so much space, even if it could be done without danger to property. It is probable, too, that many bugs would survive the burning. One locality was examined in December, 1895, and February, 1896, and the numbers of hibernating bugs noted. This place was again examined in April, 1896, after the thick grass had been burned off, and many bugs were found there still, in places next to the ground, where the fire had not penetrated thoroughly. Throughout the whole hibernating season very few dead bugs were found among those hibernating. In one case an area of a few square inches of ground, with the bugs on it as they were found hibernating, was carefully examined, and out of ninety-five bugs, ninety-two were living and three dead. A less mild winter than that of 1895–'96 might, of course, give different results.

Of the parasitic diseases of the chinch-bug, *Isaria* and *Sporotrichum* were found on bugs in winter quarters. *Sporotrichum* found on a bug near Lawrence January 6, 1896, was shown to be in a living, healthy condition by the growth of spores of the fungus when transferred to nutrient substance. In other cases the presence of living spores of *Sporotrichum* among chinch-bugs, even where there was no growth of the fungus apparent, was demonstrated in the following manner: Glass flasks were plugged with cotton in the ordinary way; then over the top of flask layers of cotton were tied in such a way that no part of the plug or mouth of the flask was exposed directly to the air. The flasks thus prepared were sterilized in a dry sterilizer, and before using were kept where they were little exposed to *Sporotrichum* kept in the laboratory.

At the hibernating places of the bugs the outer layers of cotton covering the plugs were removed, and bugs, together with a quantity of moist earth from the field, were put into the flask. The outer layer of cotton made it impossible for any spores from the laboratory to settle on the plug and the neck of the flask where they might find their way inside, and great precautions were taken to prevent any spores which might have been brought from the laboratory on the clothing or hands of the experimenter from entering the flask. So any *Sporotrichum* which might subsequently appear in the flasks would be due to spores present in the field among the hibernating chinch-bugs.

A set of flasks prepared in the above manner were supplied with chinch-bugs taken from a field near Lawrence March 31, 1896; another set were supplied from a field in Coffey county April 3, 1896, and a flask was prepared with bugs in Leavenworth county April 11, 1896. Some sterilized flasks were provided with bugs in Coffey county February 8, 1896, and although these flasks had not the outer layers of cotton, precautions were taken which made it unlikely that spores were introduced through the laboratory. In all of the four cases mentioned *Sporotrichum* appeared in one or more flasks before May 9, 1896.

Taking into consideration the case of January 6, 1896, where a transfer was made, the experiments show that living *Sporotrichum* was present among chinch-bugs during the four months of the hibernating period of 1896, and in three different counties of the state.

During the months of April and May, 1896, nineteen packages of chinch-bugs were received from farmers of Kansas, Indian territory, and Oklahoma, in which *Sporotrichum* was found already present when the packages were opened. In other cases the bugs from different localities were put into moist infection boxes as soon as they were received. There they showed *Sporotrichum* so quickly that it must be concluded that they were infected before their arrival. So we have every reason to believe that *Sporotrichum* was already present in the spring of 1896 in the localities from which these packages were sent.

Freezing Experiments.— April 16, 1896, a few bugs were taken from their hibernating quarters and placed in stout glass bottles. The day that they were captured was warm and sunny, and the bugs were very lively. Three *Sporotrichum* bugs found with them were placed in a tin box and put into the bottle with the bugs, and these were then taken to the ice factory and inclosed in a cake of ice.

On April 21, sixty-five hours after, the ice was broken and the bugs were taken from the bottle. On being warmed they became very lively, only two or three being dead. The *Sporotrichum* was placed in a moist tumbler, and on the 23d it had taken new growth and looked very fresh.

On May 1 *Sporotrichum* on agar in a test-tube was frozen up in a block of ice. After forty-three days a transfer was made from the frozen agar to sterilized beef broth, where the *Sporotrichum* demonstrated its vitality by making a normal growth.

REPORT OF A TRIP TO SOUTHERN KANSAS AND OKLAHOMA.

By Prof. W. C. Stevens.

The first calls for infected chinch-bugs in Kansas in 1896 were from Cowley and Sumner counties. There was a stretch of country, including the south-central counties and Oklahoma, where but little rain had fallen. The section was infested with bugs.

It was with great interest that the trip to the southern counties was planned, for we wished to compare the southern portions of the state with the northern respecting the condition of the bugs and the general prevalence of *Sporotrichum*.

June 22. Belle Plaine, in Sumner county, was the first place visited. On the eve of the 21st a heavy rain had fallen through-

out the dry section. Wheat on most of the farms was cut. Bugs had left the wheat in some cases two weeks previously. Twenty fields were visited, on four of which the farmers had taken special pains to distribute *Sporotrichum*. At this time the fields were very moist, and *Sporotrichum* was found in all of the twenty fields, the amount of disease depending upon the number of bugs. Where the bugs were moulting, the *Sporotrichum* was more abundant.

June 25. Arkansas City. In company with Mr. H. N. Hess, I visited farmers some of whom had used the barrier. The first farm visited was where the bugs had been very thick in the wheat and were about to leave it and enter the corn. The farmer plowed a high double furrow and rolled it down; then he applied the tar on top of the ridge where the roller had made it flat. In this way he had fenced in 160 rods of corn, using twenty-five gallons of tar. He had continued the experiment five days and the bugs had been kept out of his corn and had traveled to an adjoining farm. His corn sustained no material damage. *Sporotrichum* was found in wheat stubble and in moist places where the bugs had crossed into other fields. No artificial means had been used to infect them. We visited five other fields where the barrier method had been used, but not so successfully as in the case just described, because the post-holes were not dug and insufficient tar was used, but benefits were received in proportion to the care given. Most of the farmers had not used tar enough, thinking that one application would be enough. Fifteen fields were visited where chinch-bugs were present. *Sporotrichum* had been artificially distributed in four of these. *Sporotrichum* was found in all fields, and no difference could be seen in the conditions of the crops and number of dead bugs where *Sporotrichum* had been used and where it had not.

June 26. Perry, Oklahoma. Copious rains had visited this section at the same time as in Sumner county. The soil is a reddish clay, and, being a newly settled country, this year's crop is the first that has been raised here. Bugs were very plentiful. *Sporotrichum* was found in all places where there were bugs. The bugs were more matured than in Sumner county, because of the earlier spring here.

June 27. Winfield, Cowley county, Kansas. Visited three

corn-fields; bugs quite plentiful in all of these. *Sporotrichum* abundant.

June 27. Cherryvale, Cowley county, Kansas. Six fields were found where chinch-bugs were present. *Sporotrichum* was present in fields; in two cases it was plentiful.

Experiments with Barrier and Post-hole Traps.—We believe that the best combination barrier and trap yet proposed is the one first described in our fifth report, January, 1895. It consists of a ridge of earth, smooth, compact, and rounded, bearing along its top a line of coal-tar. The bugs are trapped in post-holes, dug to a depth of at least twenty inches, contiguous to the tar line and on the same side of it as are the bugs, and placed about fifty feet apart. This experiment, as has been stated before, is to be used when the bugs are moving from one field to another, as when they are about to enter the corn. At such times they are often massed together in incredible numbers. And in the progression toward the corn, when they reach the repellent coal-tar they move along it in an endeavor to find an opening through it and crowd themselves into the post-holes. As the holes are made larger at the bottom than at the top, the bugs cannot extricate themselves, and there perish.

The longitudinal mound or ridge should be made smooth and hard, so that the tar will not be absorbed into the ground and so that rains will have a smaller effect upon it. It is much better to lay a line of tar along a ridge than along a furrow or a level place, because the former will shed the water and the line is much less likely to be interrupted by the blowing upon it of clods, leaves, sticks, etc.

As the bugs will take advantage of every break in the line, or of the drying of it, a careful watch upon it should be kept, and it should be renewed from time to time.

The first step in the making of the ridge is to plow two closely parallel furrows, running the plow so that the earth from the furrows shall mound up between them. The resulting ridge should then be shaped and smoothed. For this purpose Mr. F. E. Marcy, an assistant of the Station, has constructed a simple drag with a concave running surface. See plates I, II, III. With such an implement the ridges can be much more quickly, easily and properly constructed than if the operator must depend upon his ordinary shovels, hoes, etc.

The following is from Mr. Marcy's notes on an experiment with the barrier:

June 6. On the farm of Mr. Eberhardt, eight miles north of Lawrence, was selected a field for experiment with the barrier method described above. This field was chosen because it showed evidence of being able to give the method a severe test. The field was located on a small creek, and is not far from the rocky hills where the bugs had hibernated. The soil was rather light and sandy, and the field broken or rolling, with deep washes in places. The field contained about ten acres. The wheat was thin, owing to the poor soil, rust, and the bugs. At this date the bugs were quite thick and hatching very fast, some of the young ones being about a week old.

June 8. Found two pupæ. Bugs are much thicker on the sides next to the corn and a few have already crossed the road and are on the corn.

June 10. With a common walking plow we turned up a double furrow between the corn and wheat, letting it extend some distance beyond the corn into the wheat and grass, so that the bugs could not get around into the corn. Then with the ridge-former we proceeded to make it ready for the salt and kerosene oil. We went over the ridge twice, going out and back, and using about 600 pounds' weight for bearing down the implement. In places where the horses had knocked down the ridge, as at the corners and ends, the ridge was repaired with a shovel before using the last time. One hundred and ninety pounds of coarse salt was used with two and a half gallons of kerosene oil. The salt was by no means saturated. The salt and oil were mixed in a wooden box with a shovel by sprinkling on a little oil and then a layer of salt, etc. Then an attachment was fastened on to the implement for distributing this mixture, which consisted of a round hopper suspended at the rear end of the implement over the center of the ridge. The bottom of this hopper was funnel-shaped, running down to an opening of one and one-half inch diameter. In the center of this was a spiral which was revolved by gears and a chain fastened to a driving wheel which followed behind the implement. It took nearly all of the 190 pounds of salt to go around the field, a distance of about seventy-five rods. Post-holes were then dug with post-hole auger to a depth of twenty to thirty inches and at a distance of about twenty paces. The time required to dig each hole was from two to four minutes. The total time consumed in plowing and forming the ridge, distributing salt and oil, digging post-holes, etc., was three hours and twenty minutes, which required the work of two men and a team. The ridge was a very good one considering the number of great weeds which were plowed under. The weeds were in some places so large that they would not allow the ridge to pack down. It would have been much better if they had been mowed off with a scythe, for a ridge that is defective in any part is little better than none. By this time the wheat was still standing and quite green, and the kernel was in the milk. The bugs were not crossing into the corn enough to do any particular damage, but the ridge was ready in case they moved toward the corn. At this time the pupæ were fast increasing in number and eggs were still hatching.

June 14. A few bugs have crossed the line in the southwest corner, where they are massed in large numbers. Renewed with fresh salt and oil at the corner, and a few other places where rabbits had broken down the line and bugs were escaping. In other places the salt is cracked or spread apart, and here the bugs are crawling through.

June 15. Ground very dry on the surface, especially on the ridge, where the sides are so steep and dusty that it is almost impossible for the bugs to get over.

In places along the ridge where the soil is moist, so that the chinch-bugs can readily climb up, they cross the salt line. The salt line was in good condition, but the odor of kerosene was almost gone from it. The kerosene was accordingly renewed by pouring a small stream from the can over the salt line.

June 16. On the southwest corner a good many bugs have crossed the ridge, not in damaging numbers, but enough to show that salt and kerosene are not a sufficient barrier at all times. In the furrow next to the ridge quite a number of larvæ in different stages were dead from the heat of the soil and exhaustion as they tried to climb up the dusty sides of the ridge. The wheat is still so green that the bugs need not leave the field on account of a lack of food. They are crossing the line a little. I renewed the line with salt and oil, using in all 190 pounds of salt and three gallons of oil; this was supplied from a pail by hand. This checked them somewhat, but they still crossed in the southwest corner.

June 17. Bugs crossed the salt and oil in southwest corner, and in places where the ridge was not too steep and dry for them to climb. Although the wheat was yet uncut, the bugs climbed over to such an extent that it was thought best to use coal-tar. This stopped their march at once. The amount used was two bucketfuls, which went around the entire ridge. Many of the young bugs died in trying to climb up the side of the ridge.

June 18. Bugs moving toward the ridge, but not crowding.

June 20. Bugs not moving any more. Rain. Renewed the line by a very small stream of tar.

June 22. Wheat uncut, but ripe. Rained in the morning. About half an hour after the rain had stopped and before the sun came out bugs were trying to cross the ridge, being especially thick at the corner or angle. A few seemed to have crossed the barrier. Tar was renewed, and trains of tar laid to guide them into the post-holes. The migratory bugs are in the black and brown larval stages principally. Some bugs are on the corn beyond the barrier.

June 24. Bugs numerous, and trying to cross the barrier. Though the tar has not been renewed since the 22d, but few bugs get across. Bugs dropping into post-holes; also crawling out again. Fixed this by running a small stream of tar along the inside next to the top.

June 25. Rained in the morning. Bugs not moving much. Rained in the afternoon. I cleaned post-holes out and renewed the tar, using a very small stream, which took about an hour's work.

June 26. Heavy rain all day.

June 27. Renewed barrier with small stream of tar; bugs not crossing. Barrier stood the rain, being washed but little.

June 29. Bugs moving but little; only a few on the ridge.

July 1. Considerable rain in the forenoon. Ridges have stood the water well; a very thin stream of tar was used.

July 2. Afternoon sunny and hot. Bugs very abundant on the ridge. Renewed by a very small stream.

July 3. Wheat cut. Bugs not moving any faster. Grass in wheat stubble very green, and in this the bugs are molting, as they have been for the last fifteen days.

July 4. Bugs are still crawling on the ridge, but none are going over. Renewed southwest corner. None of the bugs are going into the holes, as they are not thick enough to crowd each other in.

July 5. Renewed line by a very small stream of tar; bugs were crowding over in some places where the ridge had been washed out in the small ravine, and the tar had been placed on the level ground.

July 8. Renewed tar on ridge. Bugs on ridge, but none going into the post-holes, except on southwest corner.

July 9. A few bugs flying.

July 10. Renewed the tar. Bugs quite lively on the ridge; some going into the holes.

July 12. Renewed tar. More bugs on the ridge than at any other time. To-day made a new ridge, on the side marked *x*, plate II. Before plowing the double furrow we took the plow and turned a shallow furrow out, so as to cut off the sod from the ridge. This we found to be satisfactory. We did not use the shovel except in one spot where the plow would not work in the hard soil. Then we used tar mixed with different bad-smelling and offensive odors. On the part marked *x*, plate II, we used very offensive odor resembling that of skunks, phenyl isocyanide. About one gill was mixed with a bucket of tar. (A little of the cyanide was turned on to the ground in a line before the bugs, which caused them to stop at once, thus showing very clearly that it was the odor that stopped them.) On the part of the ridge marked *x2* was placed a mixture of tar and pyredine, C_5H_6N, about one-fourth of a gill with one-half bucket of tar. The ridge on the west side was next to the wall, about ten feet from it, and after we had done we found that we had bugs on both sides. Of course the greater number number were next to the stubble. A barrier on the north end of the field was made in the following manner: The plowing was done, as on the east side, by throwing the sod out and turning up a double furrow. It was leveled off with a hoe. Then a line of tar was placed on the ridge. It was very hard to get an even and compact surface on account of the lumps of dirt, so that when the tar was applied the quantity was considerably greater per rod than when the barrier implement was used. On the northwest side a barrier was made by plowing deep furrows, and then, with a shovel or hoe, the corner was cut off next to the grass side. This was found to be quite laborious. Then we made a small groove near the top side of the ridge to hold the tar; then the tar was applied. Not much was needed, as the ground was very hard. It was an easy matter to put the tar out when the narrow groove was made, but where the ridge was smooth the tar would not stay in line, but ran down at the sides in a very small stream.

July 13. Renewed the barrier on the ridge *a*. See plate II. Bugs very plentiful on this ridge but none are crossing. In a number of holes there is water, out of which they are not able to crawl. On the new ridge, marked *x*, bugs are on both sides; although the tar is fresh and the cyanide is strong they are crossing back and forth. They seem to be confused, and to show a tendency to follow each other. On the ridge marked *x2* the pyredine does not smell very strong. Renewed the barrier *b* on the north side, as it was not in as good shape as the ridge *x*. The dirt in drying fell away and cracked in a number of places. Barrier *c*, the one that was smooth, was renewed. The stream of tar that was put on was so small that it dried into the ground. Barrier *d*, the one with smooth side containing a groove, was full of dirt, so that it did practically no good. On none of the new barriers were bugs marching. Saw a few bugs flying to-day.

July 15. Bugs are very lively on the ridge and in very large quantities. They are not crossing the cyanide. Bugs on the wall or outside have disappeared. Cyanide quite strong on *x*. Could not smell the pyredine on *x2*. The parts *b* and *d* are in very good shape. On *c* the groove was filled with dirt again. Renewed all barriers.

July 17. More bugs on the ridges than on any day since the experiment commenced; they are moving in great numbers and are being rapidly caught in the holes. Estimate those in the post-holes at one-half bushel each. While the

weather is hot, it has been noticed that the time the greater number are on the ridge is from 5:00 to 6:30 P. M.; for the past few days this has been especially true. But very few bugs on *c* and *d;* more on *b*, and still greater number on *x*. Renewed all barriers, using a small stream. Gave up the pyredine, as the odor did not last over night. Used cyanide on *x* and *x2*. The part *b* takes a little more tar, the ground being dry.

July 18. Bugs not moving very much in the forenoon. Renewed barrier in southwest corner.

July 19. Rained all day.

July 20. Barrier stood the rain best on the south, west and east sides. The groove in *c* was full of mud; *d* was in good shape, and *b* was fairly good on one end. Gave up the new ridges.

July 21. Bugs almost all winged. Renewed barrier.

July 22. Bugs not moving very much.

July 27. Bugs breeding; not many on the ridge except in the afternoon, and then not a great many. Very hot—ninety-six degrees. Renewed tar.

July 29. Bugs are very lively. They seem to cross the tar more than when they were in the pupa stage; they travel much faster, and when in the grass they seem to want to hide. They are still breeding. Grass is a foot high in some places.

August 4. Bugs not plentiful; a few were on the ridge in the southeast corner. Tar and ridge in fine condition except where weeds were growing on it. Bugs in the grass; seem to have disappeared somewhere.

August 13. Not many bugs; a few in crab-grass in southwest corner.

August 22. Few bugs, and they are in the corn-field, in the crab-grass in the southwest corner.

Amount of tar used in experiment, 1 barrel, 380 pounds.
Amount of kerosene oil, 17 gallons.
Length of old ridge, 85 rods.
Length of *x* ridge, 50 rods.
Length of *b* ridge, 20 rods.
Length of *c* ridge, 10 rods.
Length of *d* ridge, 10 rods.
Amount of tar used on first ridge, 1 barrel, 7 buckets.

FINAL SUMMARY.

RESULTS OF EXPERIMENTS FOR TEN YEARS—1888-1897.

1. Chinch-bugs in any of their stages of development scarcely run the slightest risk of death on account of heavy rains, even when these are of long duration. They are inconsiderably affected by extremes of heat and cold.

NOTE.—When chinch-bugs cross *en masse* a hot, dusty road-bed, the many that die are killed by the particles of dust that enter their spiracles rather than by the heat.

2. We know of no contagious bacterial disease of the chinch-bug.

3. There are two parasitic, contagious, fungoid diseases that kill chinch-bugs, namely: *Sporotrichum globuliferum* (the "white fungus"), and *Empusa aphidis* (the "gray fungus").

NOTE.—Our experiments have to do mainly with the white fungus, as it is better understood and controlled than is the other.

4. These two diseases show their greatest virulence where the ground is damp and shaded from the direct rays of the sun and the air is humid.

5. We do not know to what extent the spores of these diseases are normally present in any given region. When they are present, whether naturally or artificially introduced, and the weather conditions are as given above, and the bugs are massed together, an outbreak of the disease will occur. The number of chinch-bugs killed in any field is approximately proportionate to the number of bugs in the field.

NOTE.—It is as true of the bugs as it is of ourselves, that the number of individuals carried away by a plague is dependent upon various conditions, such as those of weather, nourishment, density of population, etc.

6. *Sporotrichum* can be artificially communicated to healthy chinch-bugs. (*a*) It attacks bugs of all ages, but the older the bug the more easily does it succumb. (*b*) Bugs of any age that have been weakened from any cause, or injured, fall more easy victims to the disease than do those individuals that are in perfect condition. (*c*) The adults of the second brood, which in the ordinary course of events winter over and lay the

eggs for the brood of the succeeding spring, are much more successful in resisting the disease than are the adults of the first brood. (*d*) The fungus is not active in winter, and though it be present with the bugs in their winter quarters, they do not die of it, even though the winter be as mild and humid as was that of 1895–'96.

EXPENSES OF THE EXPERIMENTAL STATION,

JANUARY 30, 1896, TO JUNE 30, 1897.

Paid for material and supplies in laboratory:

Bausch & Lomb Optical Co., optical instruments and accessories	$518 52
Reinschild Chemical Co., standard meter	5 57
F. W. Jaedicke, hardware	40 05
A. Palm, hardware	2 10
Max Levy, apparatus	31 00
Scovill & Adams, photographic material	109 80
Richard Kny & Co., microscopic apparatus	170 80
E. R. Learned, oven, pans, etc.	28 05
George H. Smith, leather cases	5 50
Grovenor & Son, lumber	4 90
C. A. Pease & Son, corn-meal, meat, and salt	3 50
Hoadley & Hackman, one gross holders	1 25
Paul Schniedewend & Co., hand press	64 00
John Levett, one piece webbing	1 50
B. W. Woodward, chemicals	98
Miscellaneous hardware	8 79
Lumber	35

Paid for field agents' salaries and expenses:

F. E. Marcy	508 46
S. J. Hunter	59 50

Paid for labor in laboratories:

M. A. Barber	582 91
George J. Graves	2 40
George R. King	1 35
J. H. Henderson	1 35
Warren Miller	1 50
C. M. Sterling	12 50
Carl Wick	7 40
L. N. Flint	1 95
F. L. Snow	4 75
H. P. Cady	20
R. L. Stewart	116 80
Paid for freight, drayage, and express	27 87
Paid for postage	383 50
Paid Beal & Godding for livery in visiting fields	34 50
Total	$2,743 60

DIRECTIONS FOR USING CHINCH-BUG INFECTION.

The infected bugs received from the Station should be used to start infection boxes in the following manner:

CHARACTER AND LOCATION OF INFECTION BOX.

Make a box of seven-eighths inch material (matched white pine is best), about 24x36x6 inches. Make the cover tight-fitting, so that the bugs cannot readily escape. Weather-strips tacked about the upper edges of the box, so that the cover presses tightly against them when closed, will be found of service in keeping the bugs in. A heavy chalk-line drawn inside the box on the sides near the upper edge will greatly assist in keeping the bugs in the box.

It would be well for each farmer to have two boxes, and, after the first box has become well started, he should start the second from infection obtained from the first.

Place the boxes so as to exclude them from the sun and wind. A basement room is a good location.

TO START THE INFECTION IN THE BOXES.

Sprinkle the boxes thoroughly with water inside and out. Place an even layer of garden soil in the boxes, half an inch deep. The soil should be free from leaves or anything liable to decay. Sprinkle the soil until it is moistened through, *but not muddy*. Put a thin layer of green wheat or corn over the soil in the boxes, and distribute over this, at regular intervals, five or six of the white-fungus-covered bugs. Now put into the boxes healthy bugs from the field until they are somewhat crowded, but not packed over one another. Lastly, close and fasten down the cover.

Examine the boxes daily, and sprinkle the sides and soil as often as they appear to be getting dry. *Do not, however, make the soil muddy.* As soon as the white-fungus-covered bugs begin to increase in your boxes, you may commence to gather them for the infection of your field, but not before. You should be able to do this in three or four days. Always leave a few

fungus-covered bugs in your boxes for continued infection. Replace the green wheat or corn as often as it becomes yellow, and keep the boxes replenished with healthy bugs from the field.

TO INFECT A FIELD WITH THE WHITE-FUNGUS DISEASE.

After you are made certain by the increase of the number of bugs covered with the white fungus that the infection is working in your boxes, you should gather from the boxes dead bugs and live bugs, white-fungus covered and non-white-fungus covered, and scatter them in the field where the bugs are the thickest, in the axils of the leaves and at the bases of the stalks.

If the weather be dry, certain spots may be prepared in the field by laying corn-stalks or other vegetable refuse on the ground in sufficient quantity to produce shade and retain moisture, and thus form a favorable center for the propagation of the disease. Such spots would be excellent starting-places for field infection, as has been suggested by Professor Forbes.

If the fungus-covered bugs are abundant in the infection boxes, the earth might be taken from half of the boxes, together with the bugs, and scattered in the field. The earth should be replenished as often as removed. You should always take care, however, that some white-fungus-covered bugs remain in your infection boxes. As fast as the bugs are taken from the infection boxes they should be replaced by fresh bugs from the field. Continue to scatter bugs from the infection box over the field at intervals of two days or less, until it is seen that the bugs are dying rapidly all over the field.

CONTINUED CARE OF BOXES.

If after a time the infection boxes should give off a smell of ammonia, from the decay of bugs or bits of wheat or corn left in the boxes, the boxes should be cleaned out, earth and all, and, after airing a day, started anew as at the beginning.

Keep the earth in the boxes moist, but never make it muddy.

Sometimes other fungi than the white *Sporotrichum* appear on the bugs in the boxes. The only annoying one likely to appear is a yellowish-brown one known as *Aspergillus*. This fungus does not kill the bugs, but it may take possession of their dead bodies and become detrimental to the growth of the white fungus. If the *Aspergillus* should appear extensively in

the boxes, clean them out and burn hay in them, to kill the spores, and than start the boxes again as at the beginning.

GENERAL REMARKS.

You should save a quantity of the white-fungus-covered bugs for an early start next spring. These should be put away in tin boxes where they may be kept dry and above a freezing temperature. The fungus will remain alive in the bodies of the bugs for a year at least. Should the first lot of infected bugs from this Station seem to fail in their purpose, send without delay for a new supply.

Note carefully the chinch-bug conditions in neighboring fields, and urge your neighbors to use the infection.

NOTE.—As the legislature made no appropriation for the expenses of the Station for 1898 and 1899, each applicant for infected bugs should send twenty-five cents to pay for the assistance required in the propagation and distribution of the infection.

EXPLANATION OF PLATES.

PLATE I. Figure 1 shows the Marcy ridge-forming implement. To form the ridge, a double furrow is thrown up with the plow. The implement, which has a concave bottom, is then drawn over the ridge, compacting and smoothing it at the same time. The clod cutters shown in front were found to be superfluous, their purposes being better fulfilled by stone piled on the implement to give it more facility for pressing the clods and for scouring. The handles were found necessary for holding the implement directly over the ridge.

Figure 2 shows the implement at work. The round can attached to the rear was for the purpose of distributing salt and kerosene as the ridge was formed, but it was found more feasible to do this as a separate operation after the ridge was formed. The salt and kerosene were not found to be sufficient barriers under the meteorological conditions existing last summer. A line of coal-tar on top of the ridge was successful under all conditions.

PLATE II. Figure 1 shows a field of corn which had been destroyed by chinch-bugs as far in as the ridge shown, a little to the right of the center. After the ridge was formed and post-holes dug for traps and a stream of coal-tar run along the top of the ridge, the bugs got no further into the corn and did no more damage.

Figure 2 shows a corn-field that was protected by the ridge and post-holes before the bugs had entered the corn from the wheat. The bugs were caught in great numbers in the post-holes and perished there. Before the picture was taken the bugs were scooped from the holes and piled along the left-hand margin of the ridge, as shown in the picture. The corn suffered no damage whatever, although unprotected fields not far distant were in some instances destroyed.

PLATE III. Figures 1 and 2 show ridge formed by the Marcy implement. Post-holes were dug beside the ridge, about 100 feet apart. These should never be omitted in forming the barrier. Ridges formed in this manner are smooth and compact, and are very little affected by rain. They sometimes last throughout the summer without being seriously damaged.

PLATE IV. Figure 1 shows a reel of tarred burlap which was used for a chinch-bug barrier. Stakes were tacked to the burlap every three feet, by means of which the burlap was fastened along the ground in an upright position, as shown in figure 2. It was found that after a rain the burlap would be covered with mud which had been splattered against it, and thus rendered it inefficient as a barrier against the bugs. In fact, no device was found for all soils and seasons to equal the ridge with coal-tar and post-holes.

PLATE V. A picture taken in the field, showing scattered over the ground chinch-bugs killed by and covered with *Empusa*. In the picture the bugs appear as nearly round or oval white bodies, about one-eighth inch long. *Empusa* appeared as an epidemic only after the atmosphere had been made humid by a long rainy period; then the wholesale destruction of the bugs was very striking. *Empusa* had not been distributed by the the Station in this locality, and its appearance must have been due wholly to natural causes.

PLATE I.

Fig. 1. See pages 28, 39.

Fig. 2. See pages 28, 39.

PLATE II.

Fig. 1. See pages 28, 31, 32, 39.

Fig. 2. See pages 28, 31, 32, 39.

PLATE III.

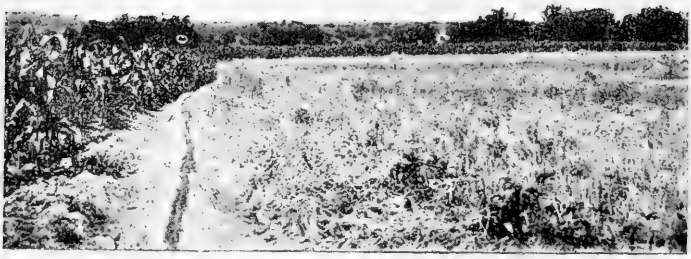

Fig. 1. See pages 28, 39.

Fig. 2. See pages 28, 39.

PLATE IV.

Fig. 1. See page 39.

Fig. 2. See page 39.

PLATE V.

See page 39.